What's food and nutrition security got to do with wildlife conservation?

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ABSTRACT

We review the linkages between food security, nutrition and wildlife conservation in the early 21st century. Declines in wildlife populations and habitats have occurred in parallel with increasing human population and the global emergence of the double burden of under- and over-nutrition. Nutrition-sensitive landscapes and nutrition- and gender-sensitive value chains are key to delivering optimal food and nutrition security and environmental outcomes. Neglected or underutilized crops and sustainable harvest of wild food have the potential to play a number of roles in the improvement of food security that include being: (a) a way to reduce the risk of over-reliance on very limited numbers of major crops and animals; (b) a way to increase sustainability of agriculture through a reduction in the carbon footprint of agriculture and maintenance of biodiversity; (c) a contribution to food quality; and (d) a way to preserve and celebrate cultural and dietary diversity. Dietary diversity and reduced greenhouse gas emissions per kilogram of animal-source food produced can be promoted through the consumption of all edible parts of the carcass, including highly nutritious offal. We argue that adopting a nutrition-sensitive landscape approach would improve consumer understanding of food systems, nutrient cycles, ecosystems services and potentially linkages between dietary diversity and biodiversity.

Key words: Food security, natural resources, sustainable agriculture, conservation, wildlife, wild food, animal-source food, maternal and child nutrition, human population, biodiversity

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Introduction

Homo sapiens evolved in parallel with species that adapted to and exploited the emerging grasslands of Africa (Kock *et al.* 2011); they fed off each other, in both an evolutionary and real sense. Humans learned to develop and use tools, with which to hunt herbivores whilst successfully defending against predators, and this gave them a competitive advantage and they proliferated. Wild or non-cultivated, non- domesticated species of both plants and animals, were critical to our species' nutritional health and growth (Milton 2003). During the past 10,000 years, the growing human population has been further sustained through the domestication of various animal species and the development of agricultural systems, as well as by continued hunting, fishing and foraging (Kock *et al.* 2011). The transition from hunting and gathering to farming has led to a narrowing of human diets, reducing diversity and impacting negatively on human nutrition (Turk 2013). The unprecedented global increase in human population over the past century has been underpinned by technological advances in agriculture, medicine and sanitation which has sustained the growth but it has been accompanied by increasing impact on ecosystems (Kock *et al.* 2011). Interdisciplinary research focusing on the intersection of humans, animals and environmental conditions has risen to prominence during the past two decades. This has been in response to complex issues as varied as (i) highly pathogenic avian influenza, which connects humans, poultry management, and wild birds (Rapport 2006); (ii) biodiversity decline due to human induced land use changes and habitat loss (Kock *et al.* 2011); (iii) poaching and consumption of 'bush meat' (a common descriptor for wild non-domesticated animal species hunted for food), linked to population pressures, a lack of livelihood opportunities, and infectious disease (Alders 2009); and (iv) non-communicable diseases resulting from modern food systems that deliver food with super-normal stimuli that is of poor nutritional value (WHO 2002). These interdisciplinary endeavors have been given a range of names over the years including:

- **One Health** – an integrative effort of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and the environment (AVMA 2008);
- **Conservation Medicine** – an interdisciplinary field with a strong focus on the integrity of ecosystems (Alders 2009);
- **EcoHealth** – a movement that recognizes that 'health and well-being are the result of complex and dynamic interactions between determinants, and between

people, social and economic conditions, and ecosystems' (Charron 2012); and most recently

- **Planetary Health** – which aims to safeguard human health and the natural systems that underpin it (Rockefeller Foundation 2015).

Here we review the linkages between food security, nutrition and wildlife conservation in the early 21st century and argue that adopting a nutrition-sensitive landscape approach would improve consumer understanding of food systems, nutrient cycles, ecosystems services and potentially link dietary diversity with recovering biodiversity.

Overview of food and nutrition security in the new millennium

Food and nutrition security has been defined as 'when all people at all times have physical, social and economic access to food, which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life' (CWFS 2012). Despite increases in agricultural production over the past two decades, malnutrition rates have not diminished significantly with undernutrition remaining a significant problem in many low-income countries and over nutrition becoming a major issue globally (Glopan 2014). These trends are reflected statistically with 200 million children under the age of five classified as having stunted growth due to chronic undernutrition, or wasting due to acute undernutrition; two billion people suffering physical and cognitive effects resulting from a lack of essential vitamins and minerals in their diets; and 2.1 billion people who are overweight or obese (Glopan 2014; Ng *et al*. 2014). Specific examples of unacceptably high stunting in children under 5 years of age include Indonesia where it remains over 30%, Papua New Guinea, Tanzania and Zambia where it affects over 40% and Timor-Leste where over 50% of children are affected (Alders, *et al.* 2014; DFAT 2015). These figures are in stark contrast to a high-income country such as Australia where in 2014-15, 63.4% of Australians aged 18 years and over were overweight or obese (35.5% overweight and 27.9% obese; ABS 2016). Crucially, these overweight and obese people frequently also suffer paradoxical nutritional deficiency from eating high-energy foods with poor nutrient content (Markovic and Natoli 2009). Changes are also evident in the human microbiome, particularly in the intestinal tract, due to 'modern' diets, which is now associated with a growing number of novel diseases and syndromes (Cho and Blasser 2012; Wu *et al*. 2011).

High levels of undernutrition, lack of education among adult women (who frequently play a key role in agricultural production, feeding of the household and care of children and sick people) and gender inequality have also shown a strong positive association with the prevalence of child undernutrition (Ivers and Cullen 2011). Malnutrition impacts on the life of the individual, their households and wider communities because of its cumulative and intergenerational (epi-genetic) impacts (Kaput 2010). The World Bank has estimated that 11% of gross national product in Africa and Asia is lost annually due to malnutrition (World Bank 2013). In terms of over nutrition, in Australia alone, the cost of overweight and obesity in 2005 was an overall total annual cost of AUD 56.6 billion (Colagiuri *et al*. 2010).

Nutrition-sensitive landscapes (Bioversity International 2014) and nutrition-sensitive value chains (Hawkes and Ruel 2012) are key to delivering optimal food and nutrition security and environmental outcomes. A nutrition-sensitive landscape approach considers the diverse interactions and interconnectivity within a given landscape to optimize the multiple goals of food and nutrition security, sustainable use of natural resources and conservation of biodiversity, both for human health, as well as environmental health (Bioversity International 2014). In order to provision people of all ages and sex with optimal nutrition in an equitable manner, specifically designed food systems and value chains that address the different needs of individuals from crib to grave is required. Nutrition and gender sensitive value chains should be responsive to the nutritional needs and gender equity issues of the actors within it (from male and female farmers, to processors and distributors) and the consumers it supplies while at the same time delivering food with a high 'cost-to-nutritional benefit' ratio (Alders *et al.* 2016; Hawkes and Ruel 2012).

In addition, given the current concerns over loss of food diversity, mobilization of neglected or underutilized crops and sustainable harvest of wild food (Figure 1) have the potential to improve food security by: (a) reducing

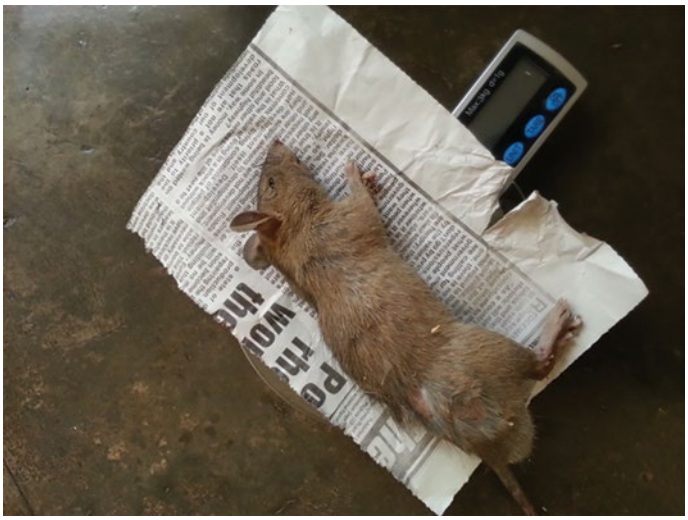

Figure 1. An ntika (*Mastomys natalensis*) being weighed in Zambia as part of a study on dietary diversity. Field rodents are hunted and consumed in many parts of Sub-Saharan Africa. (Photo: Elasto Zulu, UNZA).

the risk of over-reliance on very limited numbers of major crops and animals; (b) increasing sustainability of agriculture through a reduction in inputs, such as fossil fuel-derived nitrogen fertilizers and fuel for agriculture, given the risks of the carbon footprint of agriculture on climate change and the transition to a post peak-oil world; (c) increasing food quality; (d) preserving and celebrating cultural and dietary diversity; and (e) helping restore equilibria in the environment between microbial, vertebrate and invertebrate life with increasing pollinator resilience and a reduction in emerging crop and animal pathogens (UNEP GEO 6 2016; Wallace *et al* 2014). However, it should be noted that globally, current bush meat (Mayes *et al*. 2011) and, most probably, wild fish harvesting and consumption are ungoverned and unsustainable; this will need to be addressed. With respect to fish, artisanal small scale and diverse wild fisheries have significant nutritional benefits and low wastage profiles whilst factory ships cause havoc (Love *et al*. 2015; Kittinger *et al*. 2015). The potential benefits of diverse vertebrate and invertebrate food are also being reassessed (Yen 2009) in terms of dietary diversity and nutritional value as well as in terms of reduced animal health and agricultural input costs (van Huis 2013). If these sources of food are brought more firmly under mainstream food systems with stronger governance, there is no reason why they could not be a key component of new cyclical economies which are based on renewable or recycled resources. Finally, with respect to animal-source food, dietary diversity can be promoted through the consumption of all edible parts of the carcass, including offal (Alders 2016). Offal such as liver, provide an excellent source of bioavailable micronutrients such as haem iron (de Bruyn *et al*. 2015; Randolph *et al*. 2007). In relation to ruminant production, the efficient use of their carcass reduces the agricultural greenhouse gas emissions per kilogram of food produced (Wingett *et al*. 2016).

The food and nutrition security - wildlife conservation nexus

In many low- to middle-income countries in sub-Saharan Africa, expanding human populations have resulted in significant numbers of vulnerable people living near protected wildlife populations (Alders 2009). Some of these human populations have been dependent on wild animals and plants for their basic nutrition for millennia, living in relative harmony without negatively affecting the overall balance of biodiversity - the best example of these are the Mbendjele Yaka pygmies communities of the Congo Basin (Lewis 2002). Subsistence bush meat hunting, which makes up a significant proportion of poaching, is attributed primarily to a lack of sufficient alternative sources of protein and income, and can be equated to millions of tons of food (Fa *et al*., 2001) and is not always detrimental to the source populations where the activities are, in essence, non-commercial (Wilkie & Carpenter, 1999). There are several wildlife species, such as rodents, which continue to be hunted and consumed in many parts of Sub-Saharan Africa (Ackland 2014) without necessarily threatening these populations. From a dietary perspective, meat from wild animals is low in fat and high in essential amino acids, vitamins and minerals (Ntiamoa-Baidu 1997; Wang *et al*. 2009). In Western literature on the African continent, it is implied that bush meat harvest is illegal (Brashares *et al*. 2011) and so the term is limited to species considered worthy of conservation. The alternative and dominant development paradigm is to convert land to agriculture as the solution to the food security challenge but, in the end this is a short-term partial solution for human needs and is unsustainable if the earth is to retain self-renewing ecologies (Butler *et al*. 2007; Foley 2011; Kock *et al.* 2012). However, as economic and agricultural development leads to increased forest clearance and human settlement, conflict between incoming farmers and indigenous peoples and wildlife increases. These 'developed' communities, when they come adjacent to national parks and other wildlife conservation areas, unlike indigenous groups, often hunt wildlife unsustainably, a practice that has had severe impacts on wildlife populations globally (Milner-Gulland and Bennett, 2003).

'Golden et al. (2011) studied the impact of wildlife depletion on human health in rural northeastern Madagascar and demonstrated that consuming more wildlife (Figure 2) was associated with significantly higher haemoglobin concentrations.' The empirical models developed by Golden *et al*. (2011) demonstrated that removing access to wildlife would induce significant increase in the numbers of children suffering from anaemia. As anaemia is understood to predispose individuals to future disease, this study demonstrated the powerful and far-reaching effects of lost wildlife access on a variety of human health outcomes,

Figure 2. Lemur conservation is a priority in Madagascar. Research by Golden *et al*. (2011) revealed higher haemoglobin levels in households involved with hunting wild animals suggesting both direct and indirect benefits of hunting to household food and nutrition security. (Photo: Robyn Alders, USyd)

including cognitive, motor, and physical deficits. Golden *et al.* (2011) revealed that in the Makira Protected Area (MPA) reduced access to wild food induces a 30 percent relative increase in the prevalence of anaemia in pre-adolescent children. This research in Madagascar also determined that: wildlife hunting is occurring at an unsustainable rate in the MPA; whilst there are no alternatives to wildlife, which is an important source of nutrition for local people of the MPA, this situation will only deteriorate; alternative protein sources such as chickens (and other poultry) are a preferred food; chickens are not a secure food item due to disease outbreaks; and improving chicken health primarily through vaccination against Newcastle disease may lead to decreased hunting and overall improvement in household nutrition and income (Alders *et al.* 2012).

The sustainable control of Newcastle disease in village chickens (Figure 3) has led to significant increases in household flock sizes and consumption and decreased bushmeat consumption (Alders *et al.* 2010). An evaluation of two programs which promoted the vaccination of village chickens against Newcastle disease in southern Africa (one run by Community Markets for Conservation [COMACO] in Mambwe district, Zambia and another by the Department of Veterinary Services and the Kyeema Foundation nearby the Limpopo National Park in Gaza Province, Mozambique) revealed significantly higher flock sizes in vaccinating households (Swisher *et al.* 2010). COMACO promotes household, agricultural and ecological resilience along two strategic lines: improving recovery from shocks (mitigation) and reducing the risk of shock occurrence. A subsequent review of two of COMACO's poultry interventions suggested that addressing health and management constraints within the existing village poultry system resulted in significantly improved productivity and profitability (Dumas *et al.* 2016).

Many vulnerable rural households in southern Africa rely on village chickens for food, fertilizer, pest control, and other family needs (Alders and Pym 2009; de Bruyn *et al.* 2015). Contrary to findings in Ethiopia based on interrogation of a cross-sectional questionnaire database which suggested that overly close exposure to poultry poses a concurrent risk factor for undernutrition (Headey and Kirvonen 2016), in a two-year, longitudinal study in central Tanzania, rural households raising village chickens were found to have significantly lower rates of stunting in children under 2 years of age than households without village chickens (de Bruyn *et al.* 2016). The same study in central Tanzania found no significant relationship between stunting in children and household size, gender of the household head, level of maternal education, socioeconomic status, or cattle and small ruminant ownership. Separate analysis found no association of diarrhoea in children with chicken ownership, or with the practice of keeping chickens within human dwellings overnight. These findings support the potential of poultry-based interventions to improve nutrition in resource-poor settings. In rural households affected by HIV/AIDS, village poultry play a particularly important role because they provide a source of high quality nutrition and income without requiring much in the way of labour or financial inputs (Alders and Pym 2009). A further benefit rarely reported in literature is the conservation effect of keeping poultry. For example, in Tanzania, households raising small domestic livestock are less likely to participate in bush meat hunting (Loibooki *et al.* 2002) therefore securing the natural resource base which can also benefit communities at times of food shortage.

Conclusions

As we move forward, it is essential that the agriculture, education, health, natural resources and infrastructure sectors work together closely to ensure that food is produced, harvested and utilised optimally, effectively and safely. This is a shift away from the production paradigm where quantity and efficiency of production is a priority and, which does not consider the costs to non-human aspects of the process and externalities in general. It is this shift, which includes a strong focus on nutrient profiles and densities, that can be defined as a nutrition-sensitive landscape approach. A benefit of this approach is a heightened awareness of the importance of the ecological systems that underpin food and nutrition security.

Adequately and sustainably nourishing nine billion people by 2050 will involve direct action from the level of the soil to the plate. An Ecohealth approach (Charron 2012) to the production/harvest of sustainable, nutritious, ethical and safe food delivered with minimal waste will promote improvements to human, animal and environmental health.

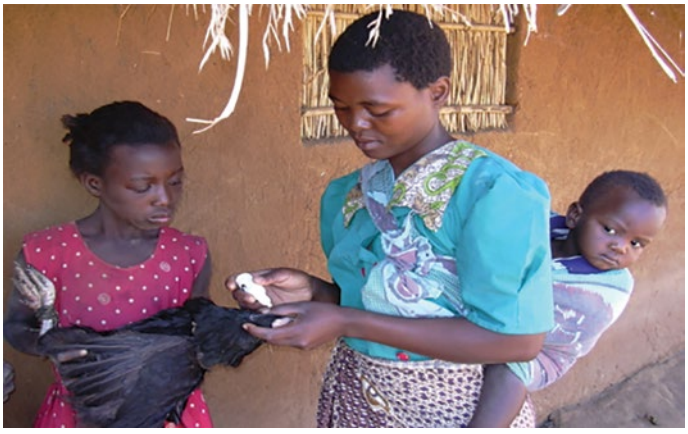

Figure 3: Village chicken health and production is significantly increased by vaccinating them against Newcastle disease (ND). Vaccination programs, employing thermotolerant ND vaccine administered via eye drop, implemented in collaboration with community vaccinators and cost-sharing with the community are key elements of sustainable ND control programs. (Photo: Robyn Alders, Kyeema Foundation)

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References

ABS. 2016. National Health Survey: First Results, 2014-15. Australian Bureau of Statistics, Canberra. Available: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/4364.0.55.001~2014-15~Main%20Features~Overweight%20and%20obesity~22

Ackland, L.A. 2014. Rodents, food security and infectious disease in Tanzania. BSc(Vet) thesis, University of Sydney.

Alders, R.G. 2009. Conservation Medicine. *Environment: Science and Policy for Sustainable Development* **51(4):** 7-8. DOI: 10.3200/ENV.51.4.7-9

Alders, R.G. 2016. Peak food and our quest for an ethical and ecologically sustainable human diet. Proceedings of the Australian Poultry Science Symposium, Sydney, Australia, 14-17 February 2016, Volume **27:** 9-13.

Alders, R., Aongola, A., Bagnol, B., de Bruyn, J., Kimboka, S., Kock, R., Li, M., Maulaga, W., McConchie, R., Mor, S., Msami, H., Mulenga, F., Mwala, M., Mwale, S., Rushton, J., Simpson, J., Victor, R., Yongolo, C. and Young, M. 2014. Using a One Health approach to promote food and nutrition security in Tanzania and Zambia. Planet@Risk (Special Issue on One Health) **2(3):** 187-190.

Alders, R.G., Bagnol, B., Crawford, G., Golden, C., Ostapak, S. and Ralaiarison, R.A. 2012. Village poultry production systems and constraints in communities bordering the Makira Protected Area in Madagascar. *World's Poultry Science Journal* **68(Suppl.1):** 916

Alders, R.G., Bagnol, B. and Young, M.P. 2010. Technically sound and sustainable Newcastle disease control in village chickens: lessons learnt over fifteen years. *World's Poultry Science Journal* **66:** 433-440. DOI:10.1017/S0043933910000516

Alders, R., Nunn, M., Bagnol, B., Cribb, J., Kock, R. and Rushton, J. 2016. Chapter 3.1 Approaches to fixing broken food systems. In: Eggersdorfer M., Kraemer K., Cordaro J.B., Fanzo J., Gibney M., Kennedy E., Labrique A. and Steffen J. (eds), Good Nutrition: Perspectives for the 21st Century. Karger, Basel, Switzerland, pp 132-144. Available online: https://www.karger.com/Article/Pdf/452381

Alders, R.G. and Pym, R.A.E. 2009. Village poultry: still important to millions, eight thousand years after domestication. *World's Poultry Science Journal* **65(02):** 181-190. DOI:10.1017/S0043933909000117

American Veterinary Medical Association (AVMA). 2008. One Health: A new professional imperative. One Health Initiative Task Force: Final report. Available online: https://www.avma.org/KB/Resources/Reports/Pages/One-Health.aspx

Bioversity International. 2014. Concept Note: Nutrition-sensitive landscapes. Bioversity International and The Earth Institute, Columbia University. Available online: https://www.bioversityinternational.org/fileadmin/user_upload/research/research_portfolio/Diet_diversity/Nutrition__Sensitive_Landscapes_Concept_paper_March_2014.pdf

Brashares, J.S., Golden, C.D., Weinbaum, K.Z., Barrett, C.B. and Okello, G.V. 2011. Economic and geographic drivers of wildlife consumption in rural Africa, Proceedings of the National Academy of Sciences **108(34)**: 13931-13936. DOI:10.1073/pnas.1011526108

Butler, S. J., Vickery, J. A. and Norris, K. 2007. Farmland Biodiversity and the Footprint of Agriculture. *Science* **315(5810):** 381-384. DOI:10.1126/science.1136607

Charron, D.F. 2012. Ecohealth Research in Practice: Innovative Applications of an Ecosystem Approach to Health. Edited by: Charron DF. Springer, New York.

Cho, I. and Blasser, M.J. 2012. The Human Microbiome: at the interface of health and disease. *Nature Reviews Genetics* **13(4):** 260–270.

Colagiuri, S., Lee, C.M., Colagiuri, R., Magliano, D., Shaw, J.E., Zimmet, P.Z. and Caterson, I.D. 2010. The cost of overweight and obesity in Australia. *Medical Journal of Australia* **192(5):** 260-4.

Crawford, G., Ostapak, S., Golden, C., Bagnol, B., Ralaiarison, R. and Alders, R.G. 2012. Improving Village Chicken Health to Decrease Bushmeat Hunting in the Makira Protected Area, Madagascar. Association of Zoos and Aquariums 2012 Annual Conference, Phoenix, AR, USA, 8–13 September 2012.

CWFS. 2012. Comprehensive Framework for Action. United Nations Committee on World Food Security, Rome.

de Bruyn, J., Thomson, P., Darnton-Hill, I., Bagnol, B., Maulaga, W., Kiswaga, G., Simpson, J., Li, M., Mor, S. and Alders, R. 2016. Village chicken ownership, irrespective of location of overnight housing, is positively associated with height-for-age Z-scores of infants and young children in Central Tanzania. One Health EcoHealth Congress. Melbourne, 3-7 December 2016, Abstract e-Booklet (oral presentation) No. 583.

de Bruyn, J., Wong, J., Bagnol, B., Pengelly, B. and Alders, R. 2015. Family poultry and food and nutrition security. *CAB Reviews* **10(13):** 1-9. DOI:10.1079/PAVSNNR201510013

DFAT. 2015. A window of opportunity: Australian aid and child undernutrition. Department of Foreign Affairs and Trade, Canberra. Available: https://dfat.gov.au/aid/how-we-measure-performance/ode/Documents/a-window-of-opportunity-australian-aid-and-child-undernutrition-2015-ode-brief.pdf

Dumas, S.E., Lungu, L., Mulambya, N., Daka, W., McDonald, E., Steubing, E., Lewis, T., Backel, K., Jange, J., Lucio-Martinez, B., Lewis, D. and Travis, A.J. 2016. Sustainable smallholder poultry interventions to promote food security and social, agricultural, and ecological resilience in the Luangwa Valley, Zambia. *Food Security* **8:** 507–520. DOI:10.1007/s12571-016-0579-5

Fa, J.E. and Peres, C.A. 2001. – Game vertebrate extraction in African and neotropical forests: an intercontinental comparison. Pp. 203-241 in Conservation of exploited species (J.D. Reynolds, G.M. Mace, J.G. Robinson & K.H. Redford, eds). Cambridge University Press, Cambridge.

Foley, J.A. 2011. Can we feed the world and sustain the planet? *Scientific American* **305:** 60 – 65. DOI:10.1038/scientificamerican1111-60

Glopan. 2014. How can Agriculture and Food System Policies improve Nutrition? Technical Brief, London, UK: Global Panel on Agriculture and Food Systems for Nutrition.

Golden, C.D., Fernald, L.C.H., Brashares, J.S., Rasolofoniaina, B.J.R. and Kremen, C. 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proceedings of the National Academy of Sciences of the United States of America* **108(49):** 19653-19656. DOI: 10.1073/pnas.1112586108

Hawkes, C. and Ruel, M.T. 2012. Reshaping Agriculture for Nutrition and Health, International Food Policy Research Institute, Washington. pp. 73-81.

Headey, D. and Hirvonen, K. 2016. Is Exposure to Poultry Harmful to Child Nutrition? An Observational Analysis for Rural Ethiopia. *PLoS ONE* **11(8):** e0160590. DOI:10.1371/journal.pone.0160590

Huber, U., Alders, R., Kock, R., Zulu, E. and Hikeezi, D. 2016. Wild foods in Bundabunda Ward Zambia: An assessment of diversity and potential contribution to food and nutrition security. Proceedings of the Agriculture, Nutrition and Health Academy Conference, Addis Ababa, 20-24 June 2016.

Ivers, L.C. and Cullen, K.A. 2011. Food insecurity: special considerations for women. *American Journal of Clinical Nutrition* **94(suppl):** 1740S-4S. DOI:10.3945/ajcn.111.012617

Kaput, J. 2010. Using genetics to tackle malnutrition. SciDevNet. http://www.scidev.net/en/opinions/using-genetics-to-tackle-malnutrition.html

Kittinger, J.N., Teneva, L.T., Koike, H., Stamoulis, K.A., Kittinger, D.S., Oleson, K.L.L., Conklin, E., Gomes, M., Wilcox, B. and Friedlander, A.M. 2015. From reef to table: social and ecological factors affecting coral reef fisheries, artisanal seafood supply chains and seafood security. PLoS One 10(8):e0123856. DOI: 10.1371/journal.pone.0123856

Kock, R., Alders, R., and Wallace, R. 2011. Wildlife, wild food, food security and human society. Proceedings of the OIE Global Conference on Wildlife: Animal Health and Biodiversity - Preparing for the Future; 23-25 February 2011, Maison de la Chemie, Paris, France. p 23.

Kock, R.A., Alders, R., and Wallace, R. 2012. Wildlife, wild food, food security and human society. In: Animal Health and Biodiversity - Preparing for the Future. Illustrating Contributions to Public Health 71-79. Compendium of the OIE Global Conference on Wildlife, 23-25 February 2011 Paris, France.

Lewis, J. 2002. Forest hunter-gatherers and their world: a study of the Mbendjele Yaka pygmies of Congo-Brazzaville and their secular and religious activities and representations. Doctoral thesis, University of London.

Loibooki, M., Hofer, H., Cambell, K.L.I. and East, M.L. 2002. Bushmeat hunting by communities adjacent to the Serengeti national park, Tanzania: The importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation* **29(3):** 391-398. DOI:10.1017/S0376892902000279

Love, D.C., Fry, J.P., Milli, M.C. and Neff, R.A. 2015. Wasted seafood in the United States: Quantifying loss from production to consumption and moving towards solutions. *Global Environmental Change* **35:**116-124. DOI:10.1016/j.gloenvcha.2015.08.013

Markovic, T.P. and Natoli, S.J. 2009. Paradoxical nutritional deficiency in overweight and obesity: the importance of nutrient density. *Medical Journal of Australia* **190:** 149–151.

Masset, E., Haddad, L., Cornelius, A., and Isaza-Castro, J. 2012. Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review. *The British Medical Journal* **344:** d8222. DOI:10.1136/bmj.d8222

Mayes, S., Massawe, F.J., Alderson, P.G., Roberts, J.A., Azam-Ali, S.N. and Hermann, M. 2011. The potential for underutilized crops to improve security of food production. *Journal of Experimental Botany* first published online November 29, 2011 doi:10.1093/jxb/err396

Milton, K. 2003. The critical role played by animal source foods in human (Homo) evolution. *Journal of Nutrition* **133(11 Suppl 2):** 3886S-3892S.

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E.C., Biryukov, S. *et al.* 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet* **384(9945):** 766-781. DOI: 10.1016/S0140-6736(14)60460-8

Ntiamoa-Baidu, Y. 1997. Wildlife and food security in Africa, FAO Conservation Guide 33, FAO, Rome.

Randolph, T.F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J.L., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J. and Ruel, M. 2007. Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science* **85:** 2788–800. DOI: 10.2527/jas.2007-0467

Rapport, D.J. 2006. Avian Influenza and the Environment: An Ecohealth Perspective. A report submitted to the United Nations Environment Program. Available: http://apps.unep.org/redirect.php?file=/publications/pmtdocuments/-Avian%20Influenza%20and%20the%20Environment_%20An%20Ecohealth%20Perspective-2006870.pdf

Rockefeller Foundation. 2015. Planetary Health. Available: https://www.rockefellerfoundation.org/planetary-health/

Swisher, S.D., Kneeland, M.R. and Alders, R.G. 2010. Evaluation of two Newcastle disease vaccination programs in Southern Africa. Proceedings of the XIII European Poultry Conference, Tours, France, 23-27 August 2010. p. 812.

Turk, J.M. 2013. Poverty, livestock and food security in developing countries. *CAB Reviews* **033:** 1–8.

van Huis, A. 2013. Potential of Insects as Food and Feed in Assuring Food Security. *Annual Review of Entomology* **58:** 563-583. DOI: 10.1146/annurev-ento-120811-153704

Wang, Y., Lehane, C., Ghebremeskel, K. and Crawford, M.A. 2009. Modern organic and broiler chickens sold for human consumption provide more energy from fat than protein. *Public Health Nutrition* **13(3):** 400–8. DOI: 10.1017/S1368980009991157

Wilkie, D. S., and Carpenter, J. F. 1999. Bushmeat hunting in the Congo Basin: An assessment of impacts and options for mitigation. *Biodiversity and Conservation* **8:** 927–955. DOI: 10.1023/A:1008877309871

Wingett, K., Allman-Farinelli, M. and Alders, R. 2016. Promoting the Direct Human Consumption of Mutton and Sheep Offal to Benefit Human Nutrition, Environmental Sustainability and Sheep Welfare in Australia. One Health EcoHealth Congress. Melbourne, 3-7 December 2016, e-Booklet (oral presentation) p. 117.

WHO 2002. Globalization, diets and noncommunicable diseases. World Health Organization, Geneva. Available: http://apps.who.int/iris/bitstream/10665/42609/1/9241590416.pdf

World Bank 2013. Stunting: The Face of Poverty. Available: http://blogs.worldbank.org/voices/stunting-face-poverty

Wu, G.D., Chen, J., Hoffmann, C., Bittinger, K., Chen, Y.Y., Keilbaugh, S.A., Bewtra, M., Knights, D., Walters, W.A., Knight, R., Sinha, R., Gilroy, E., Gupta, K., Baldassano, R., Nessel, L., Li, H., Bushman, F.D., Lewis, J.D. 2011. Linking long-term dietary patterns with gut microbial enterotypes. *Science* **334:** 105–108. http://dx.doi.org/10.1126/science.1208344

Yen, A. L. 2009. Edible insects: Traditional knowledge or western phobia? *Entomological Research* **39:** 289–298. DOI:10.1111/j.1748-5967.2009.00239.x